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PHYSICAL CHARACTERISTICS OF THE ORISKANY SANDSTONE
and
SUBSURFACE STUDIES IN THE TIOGA GAS FIELD, PENNSYLVANIA

By Charles R. Fettke

STRATIGRAPHY OF THE TIOGA REGION

By Bradford Willard

CONTENTS

Page
PHYSICAL CHARACTERISTICS OF THE ORISKANY SANDSTONE 1
    Porosity of reservoir rock 1
    Thickness of Oriskany sandstone 2
SUBSURFACE STUDIES IN THE TIOGA GAS FIELD 3
    Detailed log of the Shoemaker well 3
    Great thickness of Salina group 8
    Tully - Oriskany interval 8
    Cattaraugus-Tully-Oriskany interval 9
STRATIGRAPHY OF THE TIOGA REGION 9
    Introduction 9
    The geologic section 10
    Stratigraphy 11
        Devonian groups 11
        Silurian groups 12
    The Oriskany sandstone 12
        Stratigraphic position 12
        Lithologic character and topographic expression 12
        Faunal character 12
        Distribution of the Oriskany in New York and New Jersey 13
        Pennsylvania 13
        Attitude and general relations 13
    The red beds 13

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PHYSICAL CHARACTERISTICS OF THE ORISKANY SANDSTONE,

and

DETAILED DESCRIPTION OF A WELL LOG FROM THE TIOGA GAS FIELD, PENNSYLVANIA

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In connection with the study of the Tioga region being made by the Pennsylvania Geological Sruvey, the writer has been engaged to study in the laboratory samples of well cuttings that may become available during the progress of the work, with the object of identifying and correlating the strata penetrated by the drill. Through the courtesy of the various companies and individuals operating in the field, particularly the Penn United Gas Company, the Lycoming Natural Gas Corporation, and the Allegheny Gas Company, a vast amount of material has already been made available for study. For the field data and the collection of the samples, upon which this preliminary report is based, the writer is indebted largely to T. H. Myers, J. French Robinson, and Jack Gaddess, officials of the three companies mentioned above.

PHYSICAL CHARACTERISTICS OF THE ORISKANY SANDSTONE

All of the productive wells to date in the Tioga field have encountered the gas in the upper part of the Oriskany sandstone. This consists of a rather tightly cemented, comparatively pure, medium-grained quartz sandstone ranging in color from light gray to light brownish gray. In thin section, under the microscope, fragments blown from the productive portions are made up almost entirely of an interlocking mosaic of quartz grains possessing average diameters in the coarser portions between .5 and 1.5 millimeters and in the finer portions between .3 and .4 millimeters. In thin section the majority of the grains appear to be angular or subangular, but careful examination in many instances reveals that this angularity in part at least is due to the secondary crystalline outgrowth of silica from grains that originally were round. Such secondary silica is the chief cementing material. Thin sections of fragments from the upper portion of the sandstone blown from productive wells, as a rule, contain only a very small amount of calcite irregularly distributed among the quartz grains. This is in marked contrast to the lower portion of the sandstone which, in places where it has been penetrated by nonproductive wells is almost invariably markedly calcareous. The upper portion of the sandstone in nonproductive wells, though not as calcareous as the lower, is usually at least slightly calcareous. Inasmuch as all the productive wells stop in the upper portion, where the gas is encountered, it is not known whether the lower portion in these wells also is calcareous.

Porosity of reservoir rock. In most cases, when productive wells are drilled in, fragments of the sandstone, ranging in diameter from a fraction of an inch to an inch or even more, are blown out of the hole by the escaping gas. Porosity determinations made on a number of such fragments yielded the following results:

Well		Number of samples	Porosity Percents
Ashton	#1	6	7.9, 8.5, 8.6, 8.7, 9.5, 10.0
George Boom	#1	1	11.1
E. W. Close	#1	1	10.4
E. W. Close	#2	2	10.2, 11.2
Farr Heirs	#1	4	4.0, 4.1, 4.9, 5.0
Herrington	#1	3	10.2, 10.2, 10.6
J. A. Leslie	#1	7	8.7, 9.1, 9.8. 10.1 10.7, 11.1, 11.8
L. B. Palmer	#1	4	7.4, 7.4, 7.7, 8.5
C. H. Van Zile	#1	2	8.9, 10.6
Wilston and Kuhl	#1	2	10.0, 10.4

The average for the 32 samples tested is 9.0 per cent. It hardly seems possible that a sand of as low porosity as that of many of the fragments tested could yield such large volumes of gas as flowed from some of these wells at the time they were drilled in, even at the high pressures at which the gas was encountered. One explanation naturally is that the sand varies greatly in porosity vertically as well as horizontally and that the fragments blown out of the wells represent only the tightest portions. The occurrence of small but well developed quartz crystals, showing prism faces and terminated by pyramids, on the surfaces of most of the fragments from the Farr Heirs No. 1 well, however, suggests another possibility. Crystals of the type described could hardly develop except by growing out from a wall into an open cavity. One of the fragments shows a plane surface studded with quartz crystals. In the others, the surfaces are slightly curved. This occurrence seems to indicate the possibility that secondary cavities may have been developed by fracturing along the anticlinal axis or that the sandstone in places may be broken by shear or fault zones and that the secondary openings developed in it in this manner afford at least part and in some places possibly a major portion of the reservoir space for the gas, rather than the original pore spaces between the sand grains themselves. If the fragments blown out by the gas are typical of the formation as a whole, the pore spaces have to a considerable extent been closed by the deposition of secondary silica and in parts of the formation by carbonates. Since the above observations were first made, drilling has shown that fault zones are present in that portion of the Sabinsville anticline which has thus far proven productive.

Thickness of the Oriskany sandstone. Data on the total thickness of the Oriskany are available only from wells which encountered neither gas nor oil in the sandstone. In seven of these, rather widely scattered over Tioga County, from which the writer has received samples of the cuttings, the total thickness ranged from 23 to 82 feet, as follows:

Thickness of Oriskany sandstone, in feet

Township	Well		Total thickness	Upper, Slightly calcareous	Lower, calcareous
Lawrence	J. E. Shoemaker	#1	50	38	12
"	J. E. Tremain	#1	38	23	15
Farmington	H. C. Kemp	#1	82	37	45
Chatham	C. A. Davis	#1	28		
Brookfield	James Bertch	#1	23	10	13
Clymer	F. A. Ackley	#1	36	7	29
Elk	Weiboldt	#1	26	7	19

To date every well that has been drilled to the Oriskany horizon in Tioga County has encountered sandstone, but, as the above figures show, the thickness varies considerably from one locality to another, with an indication of thinning toward the west.

SUBSURFACE STUDIES IN THE TIOGA GAS FIELD

All of the wells drilled along the Sabinsville anticline in Tioga County start in beds of Chemung age. To date the deepest well in the county is the J. E. Shoemaker #1, located in Lawrence Township. This well was abandoned in the Vernon red shale of the Salina Group at a total depth of 7148 feet. It was planned originally to drill this well only to the Oriskany, but when this formation was found to be dry, drilling was continued with the intention of testing the deeper Medina horizon. Only 925 feet of 8¼-inch casing were set in the hole. As is shown later an unexpectedly great thickness of soft shales and salt beds was encountered at the Salina horizon. The shale and salt not only caved badly but also tended to squeeze into the hole so that reaming had to be resorted to frequently. It was finally decided that the probability of encountering commercial quantities of gas in the Medina was not sufficiently great to warrant the large additional expense that would be required to complete the test and it was, therefore, abandoned. Inasmuch as the base of the Vernon had not yet been reached and the Lockport and Clinton formations still remained to be penetrated, the top of the Medina would probably not have been encountered until a depth of 7800 to 8000 feet had been reached.

A detailed description of the strata encountered in the Shoemaker well and their correlation based upon an examination of a complete set of cuttings, follow. It is very difficult, if not impossible, to separate the Chemung Group from the Portage on lithological grounds alone and the contact shown between the two can only be considered approximate. The base of the Camillus formation of the Salina Group has been placed at the bottom of the brownish gray calcareous shale whose base is at 4424. The Syracuse continues from the base of the Camillus to the base of the shale at 6530 feet. The 495 feet of light greenish gray shale underlying this are grouped with the Vernon red shale rather than the Camillus inasmuch as they resemble the former more closely in all respects except color than they do the Camillus type of sedimentation.

Detailed Log of J. E. Shoemaker No. 1 Well,
of Lycoming Natural Gas Corporation, Lawrence Township, Tioga County, Pa.
(Based upon an examination of a complete set of cuttings).
Elevation, top of well, 1474 feet.

Thickness Feet	Description of Strata	Depth	
		Top	Bottom
24	Soil	0	24
	CHEMUNG GROUP		
61	Very fine-grained, bluish to greenish gray sandstone with minute muscovite scales	24	85
89	Bluish to greenish gray sandy shale	85	174
12	Very fine-grained, light greenish gray sandstone, slightly calcareous	174	186
135	Greenish gray sandy shale - slightly fossiliferous	186	321
6	Very fine-grained, dark grayish brown sandstone	321	327
6	Greenish gray sandy shale	327	333
17	Brownish gray sandy shale	333	350
22	Greenish gray sandy shale	350	372
6	Very fine-grained, greenish gray sandstone	372	378
356	Greenish gray sandy shale - in part slightly calcareous and containing an occasional brachiopod	378	734

7	Very fine-grained dark brownish gray sandstone - somewhat calcareous	734	741
54	Interbedded dark gray shale and greenish gray sandy shale	741	795
6	Very fine-grained dark greenish gray sandstone	795	801
96	Greenish to dark greenish gray sandy shale with some interbedded dark gray shale	801	897
57	Dark gray shale	897	954
54	Dark greenish gray sandy shale with some interbedded dark gray shale	954	1008

PORTAGE GROUP

(Contact between Chemung and Portage placed here tentatively)

6	Very fine-grained, dark greenish gray sandstone	1008	1014
6	Greenish gray sandy shale	1014	1020
6	Very fine-grained, greenish gray sandstone	1020	1026
48	Dark gray shale with some interbedded greenish gray shale	1026	1074
54	Dark greenish gray sandy shale with some interbedded dark gray shale	1074	1128
115	Dark gray shale with a little interbedded dark greenish gray sandy shale	1128	1243
116	Dark greenish gray sandy shale with some interbedded dark gray shale	1243	1359
14	Very dark gray, almost black, shale with some interbedded dark greenish gray sandy shale	1359	1373
37	Dark greenish gray sandy shale with some interbedded very dark gray shale	1373	1410
86	Dark greenish gray sandy shale	1410	1496
97	Dark gray shale with some interbedded dark greenish gray sandy shale	1496	1593
351	Interbedded dark gray sandy shale and shale	1593	1944
24	Grayish black shale with some interbedded very dark gray shale	1944	1968
43	Very dark gray shale with some interbedded grayish black shale	1968	2011
42	Very dark brownish gray sandy shale with some interbedded very dark gray shale	2011	2053
7	Very fine-grained, very dark brownish gray sandstone-slightly calcareous	2053	2060
28	Interbedded very dark brownish gray slightly calcareous sandy shale and very dark gray shale	2060	2088
367	Interbedded dark gray sandy shale and shale - slightly calcareous	2088	2455
40	Very dark gray shale	2455	2495
37	Dark gray shale with some interbedded gray sandy shale	2495	2532
80	Dark brownish gray sandy shale with some interbedded dark gray shale	2532	2612
52	Gray to dark gray shale, sandy in upper part	2612	2664
37	Gray to dark gray shale, somewhat calcareous	2664	2701
7	Very fine-grained dark gray calcareous sandstone	2701	2708
20	Dark gray shale - somewhat calcareous	2708	2728
22	Gray to dark gray calcareous shale	2728	2750

GENESEE BLACK SHALE

159	Grayish black shale - very slightly calcareous	2750	2909

TULLY LIMESTONE

50	Dark brownish gray argillaceous dense limestone	2909	2959
19	Dark gray shale - somewhat calcareous	2959	2978
13	Very dark brownish gray argillaceous dense limestone	2978	2991

HAMILTON GROUP

23	Dark gray shale - somewhat calcareous	2991	3014
24	Dark gray shale - slightly calcareous	3014	3038
67	Dark gray very calcareous shale	3038	3105
51	Very dark gray shale - slightly calcareous	3105	3156
14	Black calcareous shale	3156	3170
30	Very dark gray calcareous shale	3170	3200
145	Very dark gray shale - slightly calcareous	3200	3345
37	Very dark gray calcareous shale	3345	3382
81	Very dark gray, very calcareous shale	3382	3463

Horizon of STAFFORD LIMESTONE
(Probably in lower part of above shale)

34	Very dark gray calcareous shale	3463	3497
8	Grayish black shale - somewhat calcareous	3497	3505
15	Very dark gray calcareous shale	3505	3520
72	Grayish black shale - slightly calcareous	3520	3592
16	Very dark gray shale - slightly calcareous	3592	3608
99	Grayish black very calcareous shale	3608	3707

MARCELLUS BLACK SHALE

206	Black calcareous shale	3707	3913

ONONDAGA LIMESTONE

17	Very fine, dense gray to dark gray limestone	3913	3930

ORISKANY SANDSTONE

38	Medium-grained light brownish gray sandstone - somewhat calcareous	3930	3968
12	Medium-grained dark brownish gray calcareous sandstone	3968	3980

HELDERBERG GROUP

95	Very fine, crystalline, dark brownish gray fossiliferous limestone - somewhat siliceous and cherty	3980	4075
5	Very fine, crystalline, dark brownish gray sandy limestone - also contains some dark gray chert	4075	4080
17	Very fine, crystalline, brownish gray limestone - contains a little light gray chert	4080	4097
26	Very fine, dense, dark brownish gray, argillaceous magnesian limestone	4097	4123
24	Very fine, dense dark brownish gray, argillaceous limestone	4123	4147
21	Very fine, dense, dark brownish gray, argillaceous magnesian limestone	4147	4168
10	Very fine, crystalline, light gray, siliceous magnesian limestone	4168	4178
26	Very fine, crystalline, dark gray to brownish gray argillaceous magnesian limestone	4178	4204

TONOLOWAY LIMESTONE
(Probably contains horizons of Lower Manlius, Cobleskill, and Bertie)

57	Very fine, dense, dark gray to brownish gray argillaceous limestone with abundant crinoid stems near top	4204	4261

SALINA GROUP

Camillus Formation.

28	Very fine, crystalline, light gray anhydrite	4261	4289
13	Very dark gray shale - somewhat calcareous	4289	4302

8	Very fine, crystalline, light gray anhydrite	4302	4310
18	Very dark gray shale - slightly calcareous	4310	4328
7	Very fine, crystalline, light gray anhydrite	4328	4335
6	Very fine, dense, brownish gray argillaceous mangesian limestone	4335	4341
53	Very dark gray shale - in part somewhat calcareous	4341	4394
5	Very fine, crystalline, brownish gray anhydrite - somewhat calcareous	4394	4399
25	Brownish gray calcareous shale - contains some anhydrite	4399	4424

SYRACUSE SALT

36	Coarse, crystalline, grayish white salt **with** a little interbedded light gray shale	4424	4460
26	Light gray to brownish gray shale - slightly calcareous	4460	4486
41	Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4486	4527
6	Light gray shale - slightly calcareous	4527	4533
209	Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4533	4742
6	Light brownish gray shale - somewhat calcareous	4742	4748
20	Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4748	4768
22	Gray shale - slightly calcareous	4768	4790
127	Coarse, crystalline, grayish white salt with a little interbedded light gray shale - in part calcareous	4790	4917
75	Light gray shale - somewhat calcareous, with some interbedded salt	4917	4992
19	Coarse, crystalline, grayish white salt with some interbedded light gray shale - somewhat calcareous	4992	5011
14	Light gray shale - somewhat calcareous	5011	5025
55	Coarse, crystalline, grayish white salt with some interbedded light gray to gray shale - somewhat calcareous	5025	5080
12	Gray calcareous shale	5080	5092
6	Coarse, crystalline, grayish white salt	5092	5098
6	Gray shale - somewhat calcareous	5098	5104
16	Coarse, crystalline, grayish white salt with some interbedded light gray shale - somewhat calcareous	5104	5120
6	Light gray shale - slightly calcareous	5120	5126
6	Coarse, crystalline, grayish white salt	5126	5132
26	Light gray to brownish gray shale - somewhat calcareous	5132	5158
7	Coarse, crystalline, grayish white salt	5158	5165
184	Gray to dark gray calcareous shale with some interbedded anhydrite in upper part and salt in lower part	5165	5349
110	Coarse, crystalline, grayish white salt with a little interbedded gray shale - somewhat calcareous	5349	5459
6	Gray, very calcareous shale containing a little anhydrite	5459	5465
62	Very fine, dense, dark brownish gray argillaceous magnesian limestone containing a little anhydrite	5465	5527
25	Coarse, crystalline, grayish white salt	5527	5552
7	Very fine, dense, dark brownish gray argillaceous magnesian limestone	5552	5559
18	Very dark gray calcareous shale	5559	5577
24	Very fine, dense, dark brownish gray argillaceous magnesian limestone containing a little anhydrite	5577	5601
44	Coarse, crystalline, grayish white salt with a little interbedded brownish to dark brownish gray shale -		

13	Very fine, light gray argillaceous anhydrite - calcareous	5645	5658
32	Light gray to brownish gray shale - somewhat calcareous, with some interbedded anhydrite	5658	5690
5	Very fine, light brownish gray anhydrite - somewhat calcareous	5690	5695
87	Light gray to gray shale - somewhat calcareous containing some anhydrite in upper part	5695	5782
69	Very fine crystalline, dark brownish gray argillaceous magnesian limestone	5782	5851
12	Light brownish gray calcareous shale - contains some anhydrite	5851	5863
6	Very fine, dense, light to dark brownish gray argillaceous limestone	5863	5869
172	Light to dark gray calcareous shale - contains a little anhydrite	5869	6041
14	Coarse, crystalline, grayish white salt with some interbedded dark gray shale - somewhat calcareous	6041	6055
13	Gray to dark gray shale - somewhat calcareous	6055	6068
19	Very fine, dense, dark brownish gray argillaceous magnesian limestone	6068	6087
33	Very fine, dense, very dark brownish gray argillaceous limestone	6087	6120
14	Coarse, crystalline, grayish white salt with some interbedded gray shale - somewhat calcareous	6120	6134
13	Brownish gray very calcareous shale	6134	6147
19	Coarse, crystalline, grayish white salt with a little interbedded dark gray shale - somewhat calcareous	6147	6166
24	Very fine, dense, very dark brownish gray argillaceous magnesian limestone	6166	6190
6	Very fine, dense, very dark brownish gray argillaceous dolomite	6190	6196
37	Gray calcareous shale	6196	6233
94	Coarse, crystalline, grayish white salt	6233	6327
8	Very fine, dense, very dark brownish gray argillaceous limestone	6327	6335
7	Light gray very calcareous shale	6335	6342
7	Coarse, crystalline, grayish white salt	6342	6349
9	Gray shale - somewhat calcareous	6349	6358
60	Coarse, crystalline, grayish white salt with a little interbedded gray shale - somewhat calcareous	6358	6418
29	Dark brownish gray, very calcareous shale	6418	6447
6	Coarse, crystalline, grayish white salt with considerable interbedded dary gray shale - somewhat calcareous	6447	6453
36	Dark brownish gray, very calcareous shale	6453	6489
19	Coarse, crystalline, grayish white salt with a little interbedded dark gray shale - somewhat calcareous	6489	6508
11	Very fine, dense, very dark brownish gray argillaceous limestone	6508	6519
11	Gray to brownish gray calcareous shale	6519	6530

VERNON SHALE (Bloomsburg)

114	Light greenish gray shale - somewhat calcareous	6530	6644
44	Light greenish gray shale - slightly calcareous	6644	6688
44	Light greenish gray shale	6688	6732
43	Light greenish gray shale - slightly calcareous	6732	6775
30	Dark gray shale - somewhat calcareous - contains a little anhydrite	6775	6805
76	Light greenish gray shale - slightly calcareous	6805	6881
144	Interbedded light greenish gray and dark gray shale - somewhat calcareous	6881	7025

9	Light greenish gray shale - somewhat calcareous with some interbedded brownish red shale - also somewhat calcareous	7025	7034
91	Purplish red shale - somewhat calcareous (2-inch anhydritic seam or lense at 7060 feet)	7034	7125
23	Purplish red shale - slightly calcareous	7125	7148

Great Thickness of Salina Group. The outstanding feature presented by the log of the Shoemaker well is the great thickness of the Camillus. 2269 feet of strata possessing the characteristic features of the Camillus type of sedimentation are shown, containing a total thickness of 954 feet of salt beds.

An examination of a graphic log of the well, plotted to scale, shows no repetition in the succession of strata which can be attributed to faulting. Deviation of the hole from the vertical may account for some thickening. The well is located near the axis of the Sabinsville anticline which is fairly broad along the crest so that the dip of the strata would account for only a relatively small amount of apparent thickening.

There is one factor that may be responsible for considerable thickening. Adjustments during the period of folding of the relatively incompetent strata representing the Camillus, Syracuse and Vernon underneath the Sabinsville anticline, may have resulted in appreciable solid flow of these beds toward the axis of the anticline, thereby causing thickening. Large fragments of the light greenish gray shale from the upper part of the Vernon, brought to the surface in the bailer, are much brecciated, with interlacing calcite veinlets filling the fractures. This would seem to indicate that some such adjustments took place, but the orderly succession of the beds was not destroyed thereby. Such adjustments in the thick, incompetent strata beneath the more competent but relatively thin Helderberg and Oriskany may also be an important factor in accounting for some of the unexpected subsurface structural features revealed by drilling along the Sabinsville anticline in Farmington and Lawrence townships.

The Shoemaker well encountered the top of the first anhydrite 281 feet and the top of the first salt bed 444 feet below the base of the Oriskany. Two other wells have been drilled to the salt in Tioga County. J. E. Tremain No. 1 in Lawrence Township, located about 3½ miles southwest of the Shoemaker along the Sabinsville anticline, encountered the top of the first anhydrite bed 361 feet and the top of the first salt 568 feet below the base of the Oriskany; and H. C. Kemp No. 1, located about 9½ miles southwest of the Shoemaker, encountered the top of the anhydrite 398 feet and the top of the salt 768 feet below the Oriskany.

Tully-Oriskany interval. The most readily identifiable horizon above the Oriskany is the Tully limestone. In the Tioga region this limestone is 80 to 85 feet thick and lies approximately 1000 feet above the Oriskany sandstone. On account of the monotonous sameness of the Chemung strata in which most of the wells start and the fact that unforseen structural features may be encountered even in the areas where considerable drilling has already been done, in many cases it is hazardous to predict at just what depth the Oriskany may be expected until the Tully limestone has been reached.

Occasionally in wells drilled far down on the flanks of the Sabinsville anticline, the Tully has been mistaken for the Onondaga. Both are overlain by black shale. The Onondaga, however, is only a thin limestone in the Tioga region and, after the first or second screw has been drilled in it, the cuttings almost invariably contain particles of a brown shale which is present in the basal portion. These brown particles are easily recognized if the cuttings are examined under water on a watch glass.

The following table shows the interval between the top of the Tully limestone and the top of the Oriskany in various parts of Tioga County as determined from the examination of cuttings.

Tully-Oriskany Interval

Township	Well	Feet
Tioga	Frank Wheeler No. 1	1189
Lawrence	B. A. Buckbee No. 1	1123
"	Farr Heirs No. 1	1080
"	J. E. Shoemaker No. 1	1021
"	J. E. Tremain No. 1	1045
Farmington	Howe Estate No. 1	987
"	Charles Hoyt No. 1	914
"	H. C. Kemp No. 1	1298
"	L. B. Palmer No. 1	970
Chatham	C. A. Davis No. 1	855
Brookfield	James Bertch No. 1	737
Clymer	F. A. Ackley No. 1	1327
Elk	Weiboldt No. 1	941

Taking into consideration the geographical location of the wells listed above, only two show marked deviations from the interval which would normally be expected between the Tully and the Oriskany. These are the H. C. Kemp No. 1 and the F. A. Ackley No. 1. In the case of the H. C. Kemp No. 1, there is considerable evidence that the thickening of the interval may be due to repetition by faulting. Unfortunately a complete set of cuttings was not saved from this well so that this hypothesis cannot be verified. The Kemp well is located about 1000 feet south of the L. B. Palmer No. 1 and 3500 feet northwest of the Howe Estate No. 1.

Cattaraugus - Tully - Oriskany intervals. The writer has had an opportunity to examine cuttings from only one well which started in the Cattaraugus red beds, the formation overlying the Chemung. These came from the Weiboldt No. 1 well located along the Wellsboro anticline near Leetonia in Elk Township. Though the samples from the upper portion of this well, unfortunately were very incomplete, two samples from the upper 90 feet show definitely that the well started in the Cattaraugus. The drillers' log records the last red rock at 280 feet. The top of the Tully in this well was encountered at 5048 feet and the top of the Oriskany at 5989, making the interval from the base of the Cattaraugus to the top of the Tully 4768 feet and to the top of the Oriskany 5709 feet.

STRATIGRAPHY OF THE TIOGA REGION

By Bradford Willard

Introduction. Data on the stratigraphy of the Tioga region are obtained from the field studies, interpretation of well records, and interpolation between the concealed strata of the region and their outcrops in adjacent localities. Therefore, in this chapter will be found a discussion of the thicknesses, lithology, variations and other criteria for the recognition and interpretation of the exposed formations. An attempt is also made to describe the probable lithology, thicknesses and relations of those strata which do not come to the surface. Particular attention is given to the productive sand, the Oriskany, and to certain peculiarities of the exposed members which may have led to errors in correlation and estimation of the depth of the producing sand.

The geologic section. The exposed rocks of the field are assigned to the Pennsylvanian, Mississippian and the upper part of the Devonian systems. The subsurface rocks encountered in drilling in the field belong to the Devonian and Silurian systems. One well has been drilled into the lower part of the Upper Silurian. The post-Devonian strata may be disregarded since they are absent generally from areas of drilling. A brief discussion follows of the exposed and probable subsurface Devonian and Silurian groups.

GENERALIZED GEOLOGIC SECTION*

	Thickness in feet
DEVONIAN, exposed	
Oswayo group (upper part probably Mississippian): Cross-bedded, green or gray, relatively coarse sandstone plus occasional gray or red shales	1000±
Cattaraugus group: Red sandstone and shale with occasional green sandstones similar to overlying Oswayo with which it intergrades. Local lenses of shell limestone carry Chemung fauna, eastward. Pebble bands may occur near base. Gradual transition with underlying, non-red "Chemung"	500±
"Chemung" group (partly concealed locally) Wellsburg member: dark to drab sandstone and shale and thin, shell limestones Cayuta member: dark to bluish shale with interbedded sandstones	1500 -2000±
Portage group (concealed save for top, locally): Enfield member: dark, hard, shale, and thinbedded limestones Ithaca member: dark, shale, softer than Enfield; interbedded sandstones Sherburne member: Thin-bedded, dark gray sandstones and probably some shale	1400±
DEVONIAN, concealed	
Genesee shale: Black shale	?
Tully limestone: Gray limestone, probably present and may be the "1000-foot lime"	80±
Hamilton group: Sandstone and shale, buff to gray, some well-defined limestone lenses or limy sandstones, chiefly as shell-breccias	1000±
Marcellus shale: Black, slaty to fissile shale; locally limy, sometimes carries large, hard, siderite concretions; thickness probably varies considerably	500±
Onondaga limestone: Limestone, hard, dark gray; black cherts often abundant	40±
Oriskany sandstone: Sandstone, coarse or pebbly and friable to fine-grained or cherty, shaly or limy	50±
Helderberg group: Limestone and limy shale; gray, soft; several members recognized in outcrops	275±

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* Attention is called to the fact that any disagreement between these data and those by Alden and Fuller is due to revised interpretations.

SILURIAN, concealed

Salina group:
Chiefly shale; some salt beds, limestone and (or) dolomite (the Lockport) 2700±

Clinton group:
Sandstone and shale, gray to olive, and some limestones and thin iron ore beds 600-700±

Medina group:
Sandstone, shale and conglomerate; three members recognized, viz: 2000±
Tuscarora ------- Upper (white) Medina
Juniata ---------- Middle (red) Medina
Oswego ----------- Lower (gray) Medina

Note: Sections of these Silurian and Devonian formations are exposed in central New York and central Pennsylvania.

Stratigraphy. Devonian groups. The exposed Devonian groups are the Oswayo, Cattaraugus, "Chemung" and uppermost Portage or Enfield. The Oswayo, limited to a few, small, scattered high hills, is of little help in determining the position of the Oriskany. It consists of cross-bedded, green or gray, almost barren sandstones at the east; but westward these pass into fossiliferous beds whose fauna implies that the Devonian-Mississippian boundary may be somewhere near the top of the group. The Cattaraugus red beds represent the old "Catskill," a term better reserved as a convenient name for the Upper Devonian red beds, of whatever age. The Cattaraugus is of Chemung age, as it carries Chemung fossils in lenses of shell breccia, as in the "Burlington limestone" west of Troy and other similar beds near LeRaysville in Bradford County. The red beds pass down into non-red, marine Chemung with abundant fossils. The change is gradual, and the transition beds may be pebbly.

The term "Chemung" is here confined to the non-red, marine beds below the Cattaraugus. The non-red member is divided in south-central New York State into the upper or Wellsburg member, dominantly dark, flaggy sandstone and dark shale; and the lower or Cayuta of drab to bluish-gray shale with interbedded sandstones. The Wellsburg contains red iron ore (hematite) beds locally. Both members are so variable as to render their distinction sometimes uncertain. The hematite beds and occasional pebble bands may serve as possible horizon markers but only for short distances insofar as present investigations show.

The Portage, formerly supposed to be concealed in the Tioga region, is now identified at the surface near the axis of the Sabinsville anticline. The top of its highest member, the Enfield, is represented by a few feet of gray shale, only certainly distinguished from the overlying Cayuta by its fossils. It may be observed here that previous investigators have failed to separate the Enfield from the "Chemung" that overlies it. Hence, figures formerly given for the thickness of the "Chemung" are now believed to be excessive.

The concealed Devonian groups are dominated by monotonous, gray to drab sandstones and shales. This is as true of the Portage and Hamilton as it is of the exposed, non-red "Chemung." The succession is interrupted by the presence of a thin limestone, but most of these are probably developed only locally and are unreliable as datum planes. An exception may be the so-called "1000 foot limestone" (Tully?) discussed in Part A of this report. Also, the succession is doubtfully broken by the Genesee black shale. Below the Hamilton the lithology is more varied, and the succession is readily followed. Thus, black shale referred to the Marcellus is encountered under the Hamilton. This is in turn underlain by the persistent, hard, dark, Onondaga limestone. The Onondaga is underlain directly by the Oriskany, as Esopus has not been recognized here. In those wells going deep enough, the Oriskany is underlain by limestone and shale correlated with the Helderberg. Thus, the Devonian sequence below the base of the Hamilton is black shale, dark, hard limestone, coarse sandstone, and soft, shaly limestone.

Silurian groups. The Salina and Clinton groups should consist of dark shale with occasional limestones and perhaps a moderately thick dolomite (the Lockport) at the base of the former. The Salina group may be expected to contain rock salt. Salt and salt shale have been reported in several wells in the Tioga field, and salt occurs to great thicknesses in the Salina of central New York. The Clinton is probably chiefly gray, brown or greenish shale with some limestone and sandstone and one or more thin, hematitic iron-ore beds. The Medina group, basal Silurian, typically consists of three parts distinguished by their colors. The upper member is white, the middle red, and the lower gray. Their individual thicknesses vary in the outcrops, but the total is probably of the order of 2,000 feet. The red Medina should furnish an easily recognized datum. The nearest exposures of the Medina formation in Pennsylvania are subdivided as follows:

Logan Gap, Mifflin Co.	Feet	Mill Hall, Clinton Co.	Feet
Tuscarora - Upper (white) Medina	870	. . . .	695
Juniata - Middle (red) Medina	650	. . . .	705
Oswego - Lower (gray) Medina	250	lower part concealed . . .	900

Attention is here called to the estimates given of the thicknesses of the concealed formations. There are reasons, based upon well records and the seeming discrepancies in those, and upon field observations in Pennsylvania and New York, which imply that any of the concealed members may undergo considerable thickness changes in relatively short distances. Therefore, it is well to treat all subsurface thicknesses here given as approximations from the best data available and subject to correction as fast as new information may be secured. Thus changes in thickness may be readily appreciated by comparing the thicknesses of the Devonian in the Tioga field, as deduced, and that in the Delaware Valley between Narrowsburg and the neighborhood of Port Jervis. Data for the latter come from I. C. White's Vol. G5 of the Second Pennsylvania Survey.

Tioga region   Delaware Valley

6549 feet ------- 100 miles --------- 7170 feet

The Tioga section runs from the top of the Oswayo to the base of the Oriskany; the Delaware section from the top of the Montrose red shale to the base of the Oriskany. Thus, we have a thickening of 521 feet or slightly over 5 feet to the mile eastward.

The Oriskany sandstone. Stratigraphic position. According to the interpretation of well records the producing sand of the Tioga gas field is the Oriskany. When the first wells were drilled, there was some doubt about the horizon, as it seemed possible that it might lie in the lower part of the Hamilton; but this uncertainty can now be disregarded. The cherty strata immediately above the producing sand probably belong to the Onondaga limestone, in turn overlain by the Marcellus black shale. Below the productive sand occur limestone and shale assignable to the Helderberg. Furthermore, those wells which have been drilled deep enough to penetrate rocks assigned to the Silurian indicate that the Salina is present below the Helderberg.

Lithologic character and topographic expression. At the type locality, Oriskany Falls, New York, the Oriskany formation is a pure, light-yellow, friable, loosely cemented sandstone. From this it varies from fine conglomerate to massive, blue-white chert. Locally it is calcareous or shaly. Where the Oriskany is exposed it may form ridges or terraces, depending upon its attitude and resistance to erosion.

Faunal character. So far as known the Oriskany contains no micro-fauna suitable for identification in well cuttings. In the outcrop it carries a numerous fauna in New York, New Jersey, and eastern and central Pennsylvania as well as southward in Maryland. This fauna is dominated by large brachiopods (Spirifers and Rensselaerias) commonly preserved as casts and molds. The central Pennsylvania genera are thought to be specifically more nearly related to those of Maryland than New York. Oriskany fossils are described and figured in the following works:

Geological Survey of the State of New York, Paleontology, vol. VIII, parts 1 and 2, J. Hall and J. M. Clarke, 1893.
Geological Survey of New Jersey, Report on Paleontology III, S. Weller, 1903.
Maryland Geological Survey, Lower Devonian, 1913.

Distribution of the Oriskany in New York and New Jersey. The Oriskany is exposed as a nearly continuous, narrow band in central and eastern New York State From its westernmost known outcrop at the town of Newkirk, about 50 miles east of Buffalo, the trace is fairly regular eastward across the northern ends of Seneca and Cayuga lakes, where it is only 58 to 60 miles from the Tioga region. Except for a break southwest of Syracuse, the outcrop extends as a sinuous band, with occasional short breaks, to the Hudson Valley, 11 or 12 miles southwest of Albany. From there it continues southward, as a very thin layer, along the west side of the valley, nearly to Kingston, thence it turns south-south-west past Port Jervis and into northwestern New Jersey and then enters Pennsylvania at Wallpack bend on Delaware River.

Pennsylvania. The Oriskany has been reported, sometimes doubtfully, from nineteen counties. Its development varies. The lithology is not the same from place to place, as it may be fine conglomerate, coarse sandstone, sandy shale, or flint, or shelly, calcareous or ferruginous beds; however, it is usually a coarse, friable, light-colored sandstone. Entering the State at Wallpack bend, the formation for 35 miles southwestward underlies Godfreys Ridge, which is continued in Carbon and Schuylkill counties under the name of Steinberg Ridge for 17 miles farther. The trace becomes an irregular zigzag when it reaches Schuylkill River at Cresota, crossing and recrossing that stream, finally to be lost in Dauphin County. This disappearance seems due to faulting rather than lack of deposition, since it is again recognized at Susquehanna Gap. The formation is well developed in Perry County as a set of zigzags outcropping for about 140 miles all told. In Juniata, Mifflin, Huntingdon, and Blair counties it forms numerous outcrops, and then turns southward across the State line into Maryland.

The Oriskany has extensive development in the valleys of Susquehanna and Juniata rivers. It has been reported in Columbia, Northumberland, Montour, Snyder, and Union counties. In this region the outcrops trend back and forth as long, sinuous lines following the mountain structures. It is significant that the formation is reported as being patchy or lacking in Lycoming and Clinton counties, the district nearest the Tioga region. The Oriskany is also reported in the region of Bellefonte in Centre County.

Attitude and general relations. From the localities where it outcrops, the Oriskany sandstone, if local variations in attitude be discounted, descends generally toward the New York - Pennsylvania boundary line. Thus, its dip is gently south in central New York, west in eastern New York, northwest in New Jersey and eastern Pennsylvania, and north to northwest in central Pennsylvania. This is significant, in that, if the formation exists as a continuous sheet, it must pass under the Tioga region.

The red beds. Early students of the Devonian of New York and Pennsylvania assigned to the "Catskill formation" certain red sandstones and shales which they correlated with the Old Red Sandstone of the British Isles and which they believed overlay the marine "Chemung formation." Recent investigations have changed this interpretation of the age of the Upper Devonian red beds. The presence of marine fossils in many of them shows that they are chronologically and stratigraphically equal to rather than younger than the non-red Chemung and other Upper Devonian formations.

The red Cattaraugus beds in Tioga County are now proven to be Chemung in age, but thick, non-red Chemung underlies them. Eastward in Bradford County and beyond the red beds descend stratigraphically lower at the expense of the underlying non-red strata, which are progressively thinner in consequence. Eventually the red phase descends even below the base of the non-red, marine Chemung, so that some or all of the Portage may go over from characteristic, non-red to red beds. Evidently the base of the red beds is an eastward-descending surface progressively replacing lower, non-red formations. Estimates indicate that the base of the red beds has descended 300 feet between Tioga River and Towanda, a horizontal distance of about 35 miles. Today, probably a considerable amount of the once extant, upper, eastern portion of the red beds is eroded. For these reasons, (1) the downward progression of the base of the red beds, (2) the increasingly greater age of their base eastward, (3) their thickening eastward, and (4) the probability of considerable erosion of their upper parts toward the east, it is hazardous to place much reliance upon the base of the "Catskill" as a datum plane over more than very short distances.

The situation may be visualized if the red beds are thought of as a progressive, non-marine, westward overlap. Beginning before Upper Devonian time, the so-called "Catskill delta" was built farther and farther westward, pushing the shoreline out into central New York and Pennsylvania. Small fluctuations in sea-level may account for the occasional marine faunas found in the red beds. Either at some subsequent time or contemporaneous with this off-lap, the more easterly portions of the red beds were raised and eroded. Thus, the basal red beds grow younger westward, but their surface exposures are always older eastward; the first according to their order of deposition; the second because of subsequent or contemporaneous erosion. Finally, because of uplift to the east, the basal red beds there may today be even higher above sea level than the younger, basal red beds to the west.